DME Potential For Data Capability

Dr. Dongsong Zeng, Frank Box, John C. Ashley, Leo Globus, Dmitri V. Baraban, and Frederick A. Niles, The MITRE Corporation, McLean, VA
Brent Phillips, The Federal Aviation Administration, Washington, D.C.

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Outline

- Introduction
- DME Data Capacity with Backward Compatibility
- Some Possible Applications
- Summary
Introduction

- **Background**
  - Aviation L-band spectrum 960 ~ 1215 MHz is heavily occupied
  - Potential newcomers, such as Unmanned Aircraft System Control and Non-Payload Communications (UAS CNPC) and L-band Digital Aeronautical Communications System (LDACS), have been proposed to also use this band
  - Introducing new systems in this band is extremely challenging
  - Opportunity may exist to overlay new functions on legacy DME systems

- **Objectives**
  - Estimate DME data capacity while retaining backward compatibility with legacy DME
Distance Measuring Equipment (DME) Overview

- DME measures slant distance by transmitting/receiving pulse pairs
- 1940s technology
  - Morse Code data rate: 3 characters take 3~7 s to transmit over 1 MHz channel
  - 126 pairs of 1 MHz channels for a single navigation function
  - Modern technologies can use spectrum more efficiently

\[
\text{Slant Distance} = \frac{\text{Round Trip Delay} - \text{Transponder Delay}}{12.36 \mu s/NM}
\]
Theoretical DME Channel Data Capacity

- Shannon’s theoretical channel capacity
  - \[ C = B \times \log_2 \left(1 + \frac{S}{N}\right) \]
  - Channel capacity \( C \) is a function of
    bandwidth \( B \) and Signal-to-Noise Ratio (SNR)

- DME channel bandwidth \( B = 1 \) MHz

- When SNR = 8 dB, maximum
  instantaneous channel rate is 2.9 Mbps

- Nominal channel capacity – 2 Mbps
  - Feasible but still challenging capacity point

- To retain DME backward compatibility, the DME data waveform needs to
  share the channel with legacy DME operations resulting in reduced
  channel data rate
DME Data Capacity with Backward Compatibility

• Basic DME Analytic Model

• Basic DME Simulation Model - Matlab

• Based on these basic models, we developed analytic and simulation models for DME Data Capacity estimation
  • Results from two models are well aligned
  • To satisfy DME reply efficiency requirement of 70%, the overall duty cycle that we can transmit is about 40 ms
  • Burst-based waveform capacity is 40ms x 2Mbps = 80 kbps
## DME Data Capacity with Backward Compatibility

<table>
<thead>
<tr>
<th>Modulation Scheme</th>
<th>DME Compatible Modulation Capacities</th>
<th>Channel Data Capacities</th>
<th>Notional Modulation Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Burst-based</strong></td>
<td>2 Mbps instantaneous channel rate</td>
<td>80 kbps</td>
<td></td>
</tr>
<tr>
<td><strong>Pulse-based</strong></td>
<td>8 bits per pulse pair</td>
<td>5 kbps</td>
<td></td>
</tr>
<tr>
<td><em>Inter-pulse Spacing</em></td>
<td>5 bits per pulse pair</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Pulse Carrier Phase</em></td>
<td>3 bits per pulse pair</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Potential Applications of DME Data Capacity

<table>
<thead>
<tr>
<th>Application</th>
<th>Function</th>
<th>Data Demand</th>
<th>Data Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>DME pseudolite PNT</td>
<td>Navigation</td>
<td>0.25 kbps</td>
<td>Uplink</td>
</tr>
<tr>
<td>ARAIM ISM</td>
<td>Navigation</td>
<td>1 ~ 6 bps</td>
<td>Uplink</td>
</tr>
<tr>
<td>WAAS Correction Broadcast</td>
<td>Navigation</td>
<td>0.25 kbps</td>
<td>Uplink</td>
</tr>
<tr>
<td>TIS-B</td>
<td>Surveillance</td>
<td>3.5 kbps</td>
<td>Uplink</td>
</tr>
<tr>
<td>FIS-B</td>
<td>Surveillance</td>
<td>Variable</td>
<td>Uplink</td>
</tr>
<tr>
<td>Air Traffic Services (ATS) Data Link</td>
<td>CNS/ATM</td>
<td>40 kbps</td>
<td>Uplink and Downlink</td>
</tr>
<tr>
<td>eLORAN Data Broadcast</td>
<td>Navigation</td>
<td>15 ~ 50 bps per area</td>
<td>Uplink</td>
</tr>
</tbody>
</table>

Note: This is not an exhaustive list
Potential Evolution of DME Data Enhancement

**Today**
- Legacy DME
  - Active ranging
  - Old positioning and navigation technology
  - 126 pairs of uplink and downlink channels
  - Data rate: ~ 5 bps

**Transition**
- DME with Data Enhancement
  - Passive and active ranging
  - Multiple CNS/ATM services
  - Fully backward compatible
  - Limited data rate
  - No new spectrum required
  - Data rate: 80 kbps for Burst
    5 kbps for Pulse

**Potential Future**
- DME with Data Enhancement
  - Pseudolite ranging (no interrogation)
  - Significantly increased channel data rate
  - Support for additional CNS/ATM services
  - Data rate: up to 2 Mbps

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DME Compatible
Summary

There is potential for DME to be enhanced to:

- Enable data capability while retaining backward compatibility with legacy DME
- Enable trustable PNT service
- Use the spectrum more effectively, and provide up to 80 kbps of data capacity (burst-based modulation)
- Support additional CNS/ATM services
Thank you!

Questions?
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